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## Rethinking the regulatory treatment of securitization

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### ABSTRACT

In a model where banks play an active role in monitoring borrowers, we analyze the impact of securitization on bankers' incentives across different macroeconomic scenarios. We show that securitization can be part of the optimal financing scheme for banks, provided banks retain an equity tranche in the sold loans to maintain proper incentives. In economic downturns however securitization should be restricted. The implementation of the optimal solvency scheme is achieved by setting appropriate capital charges through a form of capital insurance, protecting the value of bank capital in downturns, while providing additional liquidity in upturns.

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### 1. Introduction

In the recent years large banks have used massively securitization (see ECB, 2004; BIS, 2008; Duffie, 2008; Minton et al., 2009, among others) in order to improve their management of credit risk. The subprime crisis has shown however that banks using securitization had grossly underestimated their resilience in the event of a macroeconomic downturn. Banks that had securitized their loans turned out to be more exposed to credit losses: first because securitization may have impaired banks' monitoring incentives and second, due to excessive leverage,<sup>1</sup> they incurred larger losses compared to other banks.

The aim of this paper is to explore the impact of securitization on bankers' monitoring incentives across different macroeconomic scenarios and derive implications for solvency regulation. In particular we address two questions: (i) Does securitization change the incentives to monitor? (ii) How should securitization be regulated through the macroeconomic cycle? We provide the following

answers: (i) incentives are preserved when capital requirements are computed on the overall size of the loans portfolio – even on the sold loans that are not on bank's balance sheet – and provided the banker retains an equity tranche in the sold loans; (ii) however securitization should not be permitted in downturns, otherwise it weakens bankers' incentives to monitor. Capital requirements should therefore be set at different levels across the different macroeconomic scenarios. This optimal solvency scheme is implemented for instance in the form of capital insurance.

Many economists have blamed banking regulators for the perverse incentives created by the regulatory treatment of securitization during the recent financial crisis, since banks active in securitization were allowed to hold less capital. Even before the crisis erupted, some commentators had expressed concerns about the effect of this massive recourse to securitization on overall risk taking by banks and on the stability of the financial system as a whole. When transferring credit risk, banks reduce their stake in the lending activity: this dilution of future claims for banks' shareholders introduces perverse incentives to shift losses onto third parties. As a consequence banks' effort to monitor loans might be weakened, as suggested by empirical evidence on securitization (Keys et al., 2010) similarly to other forms of credit risk sharing (see Mora, 2010; Ongena et al., 2012). If monitoring is important for bank credit, then securitization might increase the risk in the banking sector. Acharya et al. (2012) provide evidence that a favorable capital regulatory treatment was the motive for the increasing

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<sup>1</sup> Empirical evidence in Cebenoyan and Strahan (2004), Goderis et al. (2006) and Minton et al. (2009) shows that banks with access to securitization tend to increase their lending and hold less capital.

securitization of loans by banks; however given that the risk was not entirely shifted onto investors nor backed by increased capital charges, it caused huge losses to the banking sector.

In the paper we develop a simple model of prudential regulation of bank capital, adapted from Holmström and Tirole (1997), where bankers' monitoring reduces entrepreneurs' opportunism. Bankers are delegated monitors of borrowers on behalf of depositors. Monitoring incentives are provided through minimum capital requirements, imposed by uninsured depositors that demand bank capital as a condition to fund the bank. In this basic setup, we introduce securitization as an instance of liquidity management to extend further lending. We assume that after extending initial loans, the bank has access to new lending opportunities with positive net present value (NPV, hereafter). In order to undertake those new opportunities, the banker can sell old loans through securitization. However to preserve monitoring incentives, the banker must retain an equity tranche in the sold loans. Also capital requirements must be adjusted accordingly to preserve monitoring incentives by increasing the capital in proportion to the larger lending size. In this way, securitization may be fully accommodated in the optimal solvency scheme (a similar result is in Plantin, 2010).

The recent financial crisis has pointed to the costs of securitization. Following the macroeconomic upturn in which banks have committed to greater lending, thanks to securitization, unprecedented loans losses have started to materialize in the downturn. Normally in a recession many downgradings follow a reduction in the value of loans in the balance sheet of banks. Securitization has indeed exacerbated the amount of losses for financial institutions: Benmelech and Dlugosz (2009) provide evidence that 42% of loans writedowns in financial institutions during the recent financial crisis are due to securitized loans such as CDOs. Further Gennaioli et al. (2012) argue that financial innovation, and in particular securitization, is inherently prone to booms and busts linked to the macroeconomic cycle. To introduce costs from securitization, we assume that once banks have extended loans, their portfolio might be hit by an aggregate shock – corresponding to an economic downturn – that affects negatively loans' returns. If new lending opportunities occur after the realization of this shock, securitization cannot be optimal in all states of the economy. Indeed NPV of loans is greater in upturns compared to downturns. Thus in order to preserve incentives and make the best usage of banks' capital it is (second best) efficient to expand lending using securitization only in upturns and back it with greater capital charges; in downturns capital must be increased to cover the expected loan losses. Therefore optimal capital requirements should be state-contingent.

Our simple model of prudential regulation shows that, when taking into account banker's incentives in the different states of the economy, capital requirements should be designed either to insure for loan losses in downturns or to back the greater lending commitments in upturns. Our conclusions are partially in line with the capital insurance proposal put forward by Kashyap et al. (2008), and related to proposals by Flannery (2005, 2009). To our knowledge, this is the first attempt to model the idea of bank capital insurance in a framework where solvency regulation is endogenized by incentive considerations.

Finally notice that our approach to prudential regulation differs from the view, shared by prudential authorities, that capital is a buffer aimed at limiting the probability of a bank's failure: this is what we call the Value at Risk approach. In our view instead banks need capital to provide bankers with appropriate incentives to monitor borrowers (we call this the incentives approach). These two views have different implications for the prudential treatment of securitization. In the Value at Risk approach, securitization, by transferring credit risk outside the bank, justifies a reduction in regulatory capital requirements, for a given volume of lending. By

contrast, in the incentives approach, securitization allows to reduce capital requirements only in so far as bankers' incentives to monitor are maintained.

The remainder of the paper is organized as follows. Section 2 presents the related literature. Section 3 describes the model of capital regulation; we start from a simple benchmark model and then extend this model by introducing new lending opportunities and a solvency shock. We study the impact of these new features on the optimal mechanism. In Section 4 we show that the optimal solution can be implemented by a combination of securitization (with adequate capital charges) and capital insurance. Section 5 discusses the robustness of the results in the previous sections by challenging some of the modeling assumptions. Concluding remarks are in Section 6.

## 2. Related literature

Several papers have analyzed the impact of securitization on bank's incentives to monitor borrowers.

In Parlour and Plantin (2008) and Plantin (2010) loan sales provide liquidity for new investment opportunities, however, since monitoring is exerted before selling loans, investors cannot distinguish the true motive of the sale and therefore there could be scarcity of liquidity in the loan sales market. In contrast we explicitly disregard the adverse selection motive and assume symmetric information at the moment where banks sell their loans, in order to concentrate on the moral hazard problem between depositors and the banker. Fender and Mitchell (2009) analyze the effect of securitization on the banker's screening effort and discuss various retention mechanisms of the loans portfolio to preserve incentives; in our model incentives are maintained through equity tranche retention within a scheme of optimal capital regulation.

More generally, the benefits provided by various additional credit risk transfer (CRT, hereafter) instruments in addition to securitization, are studied in a vast literature that is less directly related to our paper, for example Gorton and Pennacchi (1995), Duffee and Zhou (2001), Arping (2004), Morrison (2005), Thompson (2006), Nicolò and Pelizzon (2008), Chiesa (2008), Pagès (2009), Parlour and Winton (forthcoming) and also the references in Kiff et al. (2003). For instance Parlour and Winton (forthcoming) analyze the effect of loan sales and credit derivatives on monitoring incentives; however they focus on the impact on loan quality when banks have superior information compared to investors and disregard prudential regulation. Morrison (2005) shows that single-named credit derivatives impact negatively on monitoring: risk-averse banks benefit from greater insurance on loan losses, but they lose incentives to monitor. Nicolò and Pelizzon (2008) analyze the impact of capital regulation on the incentives to issue different CRT instruments, and show how specific forms of credit derivatives could emerge as an optimal signaling device for better quality banks in response to exogenous capital regulations. Chiesa (2008) shows that credit derivatives insuring for aggregate risks improve monitoring incentives, while in our model the optimal balance of insurance and incentives is achieved through a combination of securitization and capital insurance. However none of these authors analyze the implications of securitization for capital regulation. Our objective, rather, is to analyze the implications of securitization on monitoring incentives together with optimal capital regulation: therefore we assume that monitoring is exerted after securitizing loans, while disregarding the implications of private information in financial markets.

Another strand of the literature analyzes how the allocation of risks across sectors in the economy changes following the participation of banks in CRT markets. For instance Wagner and Marsh

(2006) show that transfer of risk from banks to other sectors enhances welfare, when the banking sector is less diversified compared to other non-banking sectors, as the greater diversification compensates the reduction in monitoring and is beneficial for financial stability. Allen and Carletti (2006) show that under some conditions on the distribution of liquidity shocks across banks, transfers of risks from the banking sector to the insurance sector do increase financial stability. In this paper instead we focus on monitoring incentives at a representative bank level and do not consider the impact on the allocation of risks across banks or across sectors. Wagner (2007) analyses the implications of CRT for bank solvency. He shows that it improves loans liquidity by diminishing the likelihood of bank runs. However when taking into account ex-ante incentives, this greater liquidity induces greater risk-taking by the bank and thus the positive effect on bank stability is reversed.

Our paper is related to the idea of state-contingent capital regulation such as in Kashyap and Stein (2004), Flannery (2005) and more recently Kashyap et al. (2008). Kashyap and Stein (2004) have put forward the idea that capital regulation should serve both to insure loan losses and to reduce under-investment problems in the different states of the economy. As far as we know, our model provides the first attempt to examine this idea in a formalized model.

Finally, the paper is also related to the literature initiated by Froot et al. (1993), showing how appropriate risk management policies can be used in order to align better the investment capacity of a firm to its investment opportunities. We show that when regulating banks, appropriate risk management policies can be used in order to increase their investment capacity (i.e. reduce their solvency ratio).

### 3. A model of capital regulation

The aim of our model is to analyze in a tractable way the impact of securitization on the monitoring activity of banks across different macroeconomic scenarios and to derive implications for prudential regulation. We start by introducing a simple benchmark model where minimum capital requirements are the solution to the moral hazard problem between depositors and bankers. In a context where banks, whose main function is to monitor borrowers, have an incentive to exploit their informational advantage and shift portfolio losses onto depositors, minimum capital requirements provide bankers with correct incentives to monitor.

We then add to this simple benchmark model two new ingredients in order to introduce securitization and analyze its impact across different macroeconomic scenarios: an interim shock on loan returns driven by macroeconomic conditions and the possibility to undertake new lending opportunities at a latter stage. On the one hand to be able to supply lending to these new investment opportunities the bank might securitize loans. On the other hand if expected returns from loans are reduced by a macro shock, additional capital is necessary to cover expected losses instead of funding the new lending opportunities. We show that securitization together with an insurance scheme, providing capital only in the state where lending is most valuable, allows an efficient use of bank capital.

#### 3.1. A simple benchmark model

Our starting point is a simple benchmark model adapted from Holmström and Tirole (1997) to banks, as in Rochet (2004). Consider a two-date economy ( $t=0, 1$ ). At date 0 a bank, with (fixed) capital  $E_0$ , raises an endogenous volume of uninsured deposits  $D_0$  from dispersed investors and extends loans  $L_0$  to some entrepreneurs. Investors' alternative return per unit invested is

a riskless rate 1. All agents are risk-neutral and care only about expected revenues.

Entrepreneurs rely on banking finance to undertake a risky project: each project requires 1 unit of investment at date 0 and normally yields  $R > 1$  at date 1. The banker holds a portfolio of loans whose risk of default is not entirely diversifiable.<sup>2</sup> Credit risk is modeled by introducing a probability that the bank's loans portfolio suffers a loss  $\ell \in [0, R]$  per unit lent. The bank's loans portfolio is thus characterized by a probability of default  $p + \Delta p \in [0, 1]$  and a loss given default  $\ell$ . The probability of suffering losses can be reduced by  $\Delta p$  when the banker monitors loans; non-monitoring renders a private benefit  $B > 0$  per unit lent to the banker. We assume constant returns to scale both for loan returns and private benefits.

Further, we assume that there is scope for efficient monitored finance<sup>3</sup>

$$[R - p\ell] > 1 > [R - (p + \Delta p)\ell] + B, \quad (A1)$$

which requires  $\ell > (B/\Delta p)$ . The disequality on the left hand side says that the NPV of monitored loans is greater than the alternative return for investors: hence monitored finance is profitable. The disequality on the right hand side says that when a loan is not monitored it returns less than the alternative investment: investors are willing to fund bankers provided they monitor loans. Given that the monitoring effort is non-observable by outsiders, the banker is subject to moral-hazard. For the banker to monitor the portfolio of loans the following incentive compatibility condition must be fulfilled

$$(1 - p)(RL_0 - D_1) \geq (1 - p - \Delta p)(RL_0 - D_1) + BL_0,$$

where  $D_1$  is the repayment promised to uninsured depositors at date 1 in exchange for their deposits  $D_0$  at date 0.<sup>4</sup> This is equivalent to the constraint

$$b \equiv RL_0 - D_1 \geq \frac{B}{\Delta p} L_0, \quad (1)$$

where  $b$  represents the banker's reward when the bank is solvent; when instead the repayment to depositors is greater than the return of the loans portfolio,  $D_1 > (R - \ell)L_0$ , the bank defaults, repays  $(R - \ell)L_0$  to depositors and nothing to the banker.<sup>5</sup> The incentive compatibility condition can also be rewritten as

$$D_1 \leq \left(R - \frac{B}{\Delta p}\right) L_0. \quad (2)$$

<sup>2</sup> Loan losses here are not diversifiable and as a consequence the bank holds some non-diversifiable risk in its portfolio. There is a literature on the benefits of loans portfolio diversification for banker's incentives to monitor (see Diamond, 1984; Cerasi and Daltung, 2000, where the result of Diamond is applied to a context similar to the one in this paper). In our case inside equity is a perfect substitute for diversification as it fully restores incentives, as shown by Holmström and Tirole (1997).

<sup>3</sup> Given that investors are dispersed, they do not have incentives to monitor. Monitored finance can be better provided by bankers.

<sup>4</sup> Here deposits are not insured. This implies that  $D_1 > D_0$  because depositors demand a risk premium for bearing the risk of a default of the loans portfolio. In case depositors were unwilling to suffer any change in the face value of their deposits, namely  $D_1 = D_0$ , then we would have also a rational for deposit insurance. Given that depositors are risk-neutral this assumption does not affect our results as we explain at the end of this section.

<sup>5</sup> The banker's reward diminishes with loan losses and increases with the size of the portfolio of loans. It is possible to show that this reward implies rewarding the banker only if loan losses are below  $\ell^*$ , setting  $b(\ell) = \ell^* L_0$  when  $\ell \leq \ell^* = B/\Delta p$ , and 0 otherwise. In the model we assume that the distribution of losses  $\ell$  is Bernoullian, namely  $\tilde{\ell} = \ell$  with probability  $p$  and  $\tilde{\ell} = 0$  with probability  $(1 - p)$ . In Appendix B we generalize the problem to the case of a continuous loan losses probability function  $F(\ell)$ .



Given that depositors do not observe the monitoring effort and that the banker derives a private benefit from not monitoring, she cannot credibly promise to repay depositors an amount greater than the maximum pledgeable income defined by the right-hand side in (2).

Date 0 bank's balance sheet is defined as

$$L_0 = E_0 + D_0. \quad (3)$$

The participation condition for depositors, when the banker monitors, is

$$(1 - p)D_1 + p(R - \ell)L_0 \geq D_0, \quad (4)$$

and after substituting (3), it becomes

$$E_0 \geq [1 - p(R - \ell)]L_0 - (1 - p)D_1. \quad (5)$$

In this simple model the capital adequacy requirement is the solution to the moral hazard problem between the banker and depositors. We make the following assumption:

$$R - p\ell - (1 - p)\frac{B}{\Delta p} < 1. \quad (A2)$$

**Proposition 1.** *The (second-best) solution implies a capital adequacy requirement limiting banks' lending to a certain multiple of their equity, that is*

$$L_0 \leq \frac{E_0}{k_S}$$

where  $k_S \equiv 1 - R + (B/\Delta p) + p(\ell - (B/\Delta p))$ , which is positive by (A2), can be interpreted as a (simple) capital ratio.

**Proof.** The banker's problem requires choosing the level of loans  $L_0$  and deposits  $D_0$  that maximize expected social surplus

$$S = [R - p\ell - 1]L_0$$

subject to the incentive compatibility constraint (2) and depositors' participation condition (4). Given (A1) the expected social surplus is increasing in the amount of lending  $L_0$ . The optimal solution is obtained by substituting the binding incentive constraint (2) into (5). We thus obtain the maximum volume of lending

$$E_0 = \left[1 - R + \frac{B}{\Delta p} + p\left(\ell - \frac{B}{\Delta p}\right)\right] L_0. \quad \square$$

Assumption (A2) means that the maximum expected return that depositors can obtain while preserving bankers' incentives (the left hand side of (A2)) is less than 1. This implies that banks need capital, i.e. that  $k_S = 1 - R + B/\Delta p + p(\ell - (B/\Delta p)) > 0$ . In other words, there is need of a minimum level of "informed" capital  $k_S$  to cover expected loan losses and to repay the banker for her effort. From Proposition 1 it follows that banks can expand their lending up to a maximum of  $1/k_S$  of their equity. A greater capital ratio implies tighter credit conditions.

Note that our simple model delivers implications for the design of capital requirements.<sup>6</sup> Our capital ratio decreases with the return  $R$  on loans and increases with the intensity of moral hazard, measured by the ratio  $B/\Delta p$ . In addition, it increases with expected shortfalls since the last term  $p(\ell - (B/\Delta p))$  coincides with depositors' expected shortfall  $p[D_1/L_0 - (R - \ell)]$  when the incentive constraint (2) is binding. Thus our incentives-based capital ratio behaves more like an expected shortfall (or Tail VaR) measure rather than a VaR (Value-at-Risk), although like a VaR indicator

our capital ratio increases with expected loan losses  $\ell$  and default probability  $p$ .

To summarize, the solution in Proposition 1 requires the banker to self-finance a sufficiently large fraction of her loans as a condition for depositors to fund themselves the banker, very much in the way that private financiers require corporations to finance with own capital a sufficient fraction of their investment projects. This self-regulation solution can be interpreted also as the optimal prudential regulation scheme when we assume that the regulator, acting in the interest of depositors, does not observe the banker's effort (see Dewatripont and Tirole, 1999 for a detailed discussion of this representation approach to banks' prudential regulation): in that case the optimal prudential scheme would require a fairly priced deposit insurance in addition to the minimum capital ratio  $k_S$ .

### 3.2. The model with macroeconomic uncertainty

We now add two ingredients to the simple benchmark model: new lending opportunities and a macroeconomic shock to the value of the loans portfolio. These two ingredients enable us to introduce securitization and analyze its impact on monitoring incentives across different macroeconomic scenarios in a simple theoretical framework.

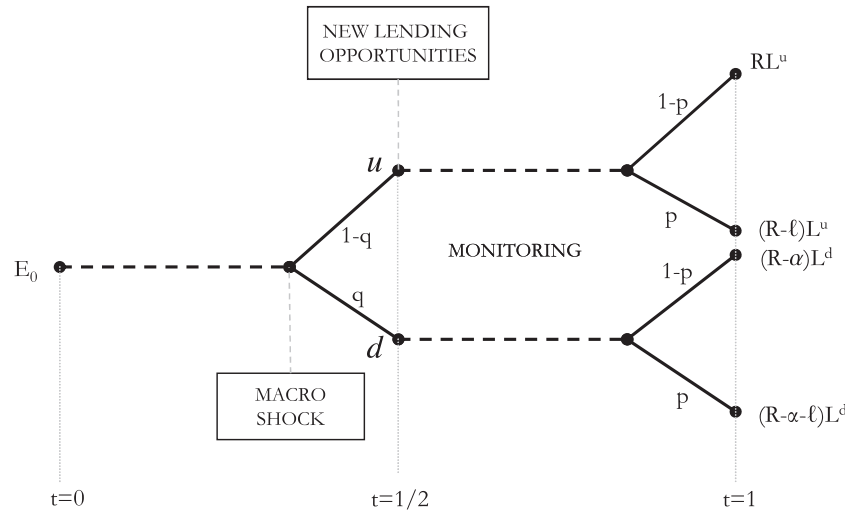
New lending opportunities arise at an intermediate date between 0 and 1. More specifically, we assume that at date 1/2 the banker has the possibility to extend new loans of the same quality as the old ones, leading to a total volume of  $L = (1 + x)L_0$  with  $x \in [0, \beta]$ . This means that there is the possibility that new valuable financing opportunities become available once the banker has already extended  $L_0$  loans in the first stage.<sup>7</sup> To be able to expand loans by  $xL_0$  at date 1/2, the banker can resort to new investors in financial markets.

Further, we model the state of the macroeconomy by adding an exogenous solvency shock that affects the expected return on the loans portfolio in the worse scenario. More specifically, we assume that between dates 0 and 1/2 (after the banker has extended initial loans  $L_0$  but before the new opportunities arise) a publicly observable shock occurs (say, a recession) with probability  $q \in [0, 1]$ : in this event the loans portfolio only returns  $(R - \alpha)$ , instead of  $R$ . The parameter  $\alpha \in (0, R)$  can be interpreted as the actual loss that materializes at the later date 1 when there is a recession. Note that new lending opportunities arise at the same rate  $\beta$  regardless of the state of the economy. Hence the difference between the two macroeconomic states is that in recession loan losses are larger. To summarize, there are two kinds of credit losses:

- Exogenous credit losses  $\alpha$  associated with the aggregate state of the economy: either an upturn where the value of loans is preserved (no credit loss) or a downturn where credit losses are  $\alpha$  per unit lent. The loss  $\alpha$  is exogenous, since it is independent upon the effort of the banker. The state of the economy is observable and verifiable, so that contracts can be written contingent on this state.
- An endogenous credit loss  $\ell$  whose probability can be reduced from  $p + \Delta p$  to  $p$  when the banker exerts monitoring effort. Although the credit loss  $\ell$  is observable, the banker's monitoring effort is not.

<sup>7</sup> The assumption that the new loans are a percentage of old loans is not crucial, but simplifies the algebra. In addition, we assume that their return is equal to the old loans to eliminate results driven by arbitrage across different type of loans. In contrast to stage financing however, the new loans cannot depend upon the past performance of the old loans as the old ones have not reached their maturity yet.

<sup>6</sup> In Appendix B we show that the main flavor of this result remains when introducing a more realistic model of default risk.



**Fig. 1.** The expected returns of the portfolio of loans and the timing. The figure shows the returns of the loans portfolio in each of the different states together with the timing of the model. At date 0 the bank with capital  $E_0$  lends  $L_0$ . Between dates 0 and 1/2 an exogenous macro shock occurs: if with probability  $(1-q)$  the state of the world is “u” (upturn) the portfolio returns  $R$  per loan, otherwise with probability  $q$  state “d” (downturn) occurs and the unitary return is  $(R-\alpha)$ . After the realization of the macro shock, new financing opportunities arise and the banker might decide at date 1/2 to extend lending up to  $\beta L_0$  in both states of the world, so that total loan size might be  $L^u$  in state  $u$  or  $L^d$  in state  $d$ . Afterwards, the banker exerts monitoring effort to reduce the probability of loan losses  $\ell$ .

After the realization of the shock and after new loans have possibly been funded, the banker decides whether or not she monitors the overall portfolio of loans.<sup>8</sup> If she does, she reduces the probability of endogenous credit losses  $\ell$  by  $\Delta p$ . We assume that even in downturns, monitored loans remains profitable:

$$R - p\ell - \alpha > 1. \quad (A3)$$

Fig. 1 might help clarify the sequence of events and total revenues. The upper branch variables are denoted by a superscript  $u$  (upturn), while the lower branch variables are denoted by a superscript  $d$  (downturn).

For the banker to monitor the portfolio of loans, an incentive compatibility constraint similar to (1) must hold in each state:

$$b^u \geq \frac{B}{\Delta p} L^u, \quad b^d \geq \frac{B}{\Delta p} L^d, \quad (6)$$

where  $b^s$  denotes the banker's bonus<sup>9</sup> in state  $s$ , while  $L^s$  denotes the size of the loans portfolio in state  $s$  (with  $s = u, d$ ). The banker's payoff is equal to the difference between loans' revenues and the sum of repayments of the banker to depositors and investors, as it will become clear in what follows.

From an ex-ante perspective, depositors are willing to fund the bank at date 0 if the face value of deposits  $D_1$  at date 1 or what is left in case the loans portfolio defaults, is at least equal to  $D_0$ , that is whenever their participation constraint holds

$$(1-q)[(1-p)D_1 + p(R-\ell)L^u] + q[(1-p)D_1 + p(R-\alpha-\ell)L^d] \geq D_0 \quad (7)$$

<sup>8</sup> This timing simplifies the model as it avoids being concerned about the lemon problem on the quality of the loans in the bank portfolio. The bank acquires information on loans, through monitoring, after raising funds from financial markets. Therefore the bank is as informed as investors about the quality of loans in her portfolio. Plantin (2010) discusses the effect of anticipating the timing at which monitoring occurs in a model similar to this. He analyses the costs of securitization when the banker monitors before selling loans: the lack of commitment in the sale of loans may cause a liquidity problem in those markets.

<sup>9</sup> Throughout the paper we neglect possible agency problems between the managers and the shareholders of the bank: what we call the “banker” represents the coalition of the two. If there is a possible conflict of interest between managers and shareholders, control of managers' remunerations by regulators might be a necessary complement to capital requirements.

Similarly, new investors are willing to inject new funds at date 1/2 if and only if their expected revenue matches at least the opportunity cost of the capital they have invested in the bank:

$$(1-q)(1-p)[RL^u - b^u - D_1] + q(1-p)[(R-\alpha)L^d - b^d - D_1] \geq [(1-q)x^u + qx^d]L_0. \quad (8)$$

The left hand side of this condition, the participation constraint of investors, is the expected return of the loans portfolio when successful, after repaying depositors and the banker. The right hand side is the expected opportunity cost of their funds. These new investors must be endowed with a greater risk appetite compared to depositors funding the bank at date 0.<sup>10</sup>

The optimal solution is now characterized by the vector  $(L_0, x^u, x^d)$  that maximizes expected social surplus

$$S = (1-q)[R - p\ell - 1]L^u + q[R - \alpha - p\ell - 1]L^d \quad (9)$$

under constraints (6)–(8) and the feasibility conditions  $x^u, x^d \in [0, \beta]$ . The control variables are the volume of lending  $L_0$  at date 0 and the liquidity injections by new investors at date 1/2, respectively  $x^u L_0 = L^u - L_0$  and  $x^d L_0 = L^d - L_0$ .

**Proposition 2.** The (second best) solution is characterized by an initial volume of lending limited to

$$L_0 \leq \frac{E_0}{k_0}$$

where  $k_0 \equiv (1-q)(1+\beta)k_s + q(k_s + \alpha)$  denotes the modified capital ratio at date 0. Moreover  $x^u = \beta, x^d = 0$ : at date 1/2 the banker is allowed to expand lending only in upturns but not in downturns.

**Proof.** See in Appendix A.  $\square$

The optimal solution implies setting different expansion rates for lending across states, namely  $x^u = \beta$  and  $x^d = 0$ . In other words the banker is allowed to lend at full capacity only in upturns, not in downturns. Note that the rate at which new lending opportunities arise is identical across states, therefore the different expansion

<sup>10</sup> These new investors bear the macroeconomic risk. This point is further discussed in Section 5.

rates do not depend by different opportunities across states, but to the fact that monitoring is more valuable in upturns (where its marginal benefit is greatest).<sup>11</sup> To foster monitoring incentives, the solution requires stretching the difference in banker's earnings between state  $u$  and state  $d$ , given by  $(b^u - b^d) = (B/\Delta p)(x^u - x^d)L_0$ . An increase in  $L_0$  alone would not reward the effort in state  $u$  more than in state  $d$ . To reach a difference in rewards for the marginal effort, the difference in lending rates  $(x^u - x^d)$  must be set apart as far as possible.

The modified capital ratio reflects this property and it allows implementing the (second best) optimal volume of lending in each state. In upturns the banker is allowed to expand by  $\beta$  its initial lending: if we apply the simple capital ratio  $k_S$  to this larger lending base we obtain a capital requirement  $E^u = k_S L^u = k_S(1 + \beta)L_0$  and a contingent capital ratio  $k^u = (1 + \beta)k_S$ . In downturns the lending base remains  $L_0$  but the expected return on loans is smaller due to the exogenous loan losses: the capital requirement must become  $E^d = (k_S + \alpha)L_0$  associated with a contingent capital ratio  $k^d = k_S + \alpha$ . The ex-ante capital ratio  $k_0$  (at date 0) is the weighted average of these two different capital ratios, which are set at different values conditional on the macroeconomic state:

$$k_0 = (1 - q)k^u + qk^d.$$

To conclude, the capital ratio must be tighter in each of the two macroeconomic states but for a different reason: in state  $u$  more capital is needed in order to expand lending, while in state  $d$  more capital is needed to cover the exogenous credit losses on the loans portfolio.

#### 4. Securitization with capital insurance

In this section we show how the optimal solution derived in Proposition 2 can be implemented through a combination of securitization and capital insurance.

**Securitization.** To be able to supply new business opportunities in upturns the banker raises new funds  $\beta L_0$  from investors at date 1/2. One way to achieve this is to sell a fraction  $y$  of initial loans to investors in financial markets. The optimal fraction of the portfolio of loans that needs to be sold to preserve the banker's incentive to monitor, can be derived as follows. The banker must be rewarded  $B/\Delta p$  per loan in case the bank is solvent, while 0 in the event of default: this is equivalent to say that the banker must retain an equity tranche in the sold loan to preserve her incentive to monitor the loan.<sup>12</sup> On each of the sold loans, thus investors earn  $(R - (B/\Delta p))$  if the loan succeeds, and  $(R - \ell)$  in case the loan defaults. The price the new investors funding the bank at date 1/2 are willing to pay for each sold loan must be equal to its expected revenue

$$P = (1 - p)\left(R - \frac{B}{\Delta p}\right) + p(R - \ell) = 1 - k_S \quad (10)$$

that is, investors gain from the return on the loan once the bonus to the banker has been paid. This price is the maximum price that new investors are ready to pay for the non-equity tranche of the

loans portfolio. Note that, due to assumption (A2), it follows that  $P < 1$ .

To be able to extend new loans, the banker has to sell a proportion of old loans  $y$  such that  $yP = \beta$ , that is

$$y = \frac{\beta}{1 - k_S} > \beta.$$

Since the banker has to retain a stake in initial loans (in order to maintain her monitoring incentives), this leads to a number of sold loans that exceeds the number of new loans:  $y > \beta$ .

The optimal solution described in Proposition 2 requires in addition a system of capital insurance. Given that total lending is constrained by the maximum pledgeable income to depositors which differs across states, the banker can smooth this difference and doing so she boosts lending and saves bank capital. This is why some form of state-contingent transfers across states is needed. As we will explain, this can be interpreted as capital insurance.

**Capital insurance.** To implement the optimal solution, state-contingent transfers are needed in addition to securitization. The banker can in fact sign with new investors an insurance contract at date 0 to commit to transfer money across the two states once the uncertainty is resolved. This can be interpreted as a state-contingent contract where the banker commits to pay those new investors  $T^u$  in state  $u$  and  $T^d$  in state  $d$  once date 1 is reached.<sup>13</sup> For this contract to be fairly priced, the contingent transfers  $T^u$  and  $T^d$  must fulfill the condition

$$qT^d + (1 - q)T^u = 0.$$

We can state the following result.

**Proposition 3.** *The optimal solution can be implemented by the following series of capital ratios:*

$$k_0 = (1 - q)(1 + \beta)k_S + q(k_S + \alpha) \quad (11)$$

at date 0, and two state-contingent capital ratios at date 1:  $k_S$  in state  $u$  and  $k_S + \alpha$  in state  $d$ . Given that the banker increases the volume of loans by a fraction  $\beta$  in state  $u$ , regulatory capital must equal (at least)  $k_S(1 + \beta)L_0$  in state  $u$  and  $(k_S + \alpha)L_0$  in state  $d$ . Regulatory capital at date 0 equals the expected value of regulatory capital in the two states.<sup>14</sup> New loans are financed through securitization only in state  $u$  by selling a fraction

$$y = \frac{\beta}{1 - k_S}$$

of initial loans. In state  $d$ , the banker is not allowed to issue new loans. Finally adjustments in regulatory capital are provided by contingent transfers paid by the bank to investors:

$$T^u = qWL_0; \quad T^d = -(1 - q)WL_0$$

$$\text{with } W \equiv \left[\alpha - y\left(R - \frac{B}{\Delta p}\right)k_S\right].$$

**Proof.** See in Appendix A.  $\square$

To get the intuition for the result in the proposition, let us first consider the case with  $\alpha = 0$  and  $\beta > 0$ , that is without macro shocks but with new lending opportunities at date 1/2. In this case the

<sup>11</sup> If we had different values of  $\beta$ , with  $\beta_u > \beta_d$ , the solution would be to expand lending up to  $\beta_u$  since the NPV of loans is greater in upturns given the loan losses  $\alpha$  in downturns.

<sup>12</sup> The result of optimality of equity tranche retention for incentives is not new: Fender and Mitchell (2009) for instance show that it is one of the possible solutions to revitalize securitization markets in the wake of the recent financial crisis. We show that the solution of equity tranche retention must be backed by tighter capital requirements, due to the greater risk of default for the banker as suggested by the empirical evidence in Acharya et al. (2012).

<sup>13</sup> The same result can be obtained with an insurance contract where the banker pays a fair premium at date 0, in order to have a state contingent refund at date 1. In both interpretations when the bank is insolvent the refund is cashed directly by depositors, otherwise by bank's shareholders.

<sup>14</sup> In our simple model, the capital ratio is always binding for the bank (both at date 0 and in each of the two states as explained at the end of the current section). In a more complex model, we could obtain a difference between economic capital and regulatory capital. This would require introducing more periods and possibilities for the bank to issue more capital or distribute dividends.

only possible state of the economy is state  $u$ : since the expected surplus is increasing in the total amount of lending, all new business opportunities must be financed, i.e.  $L^u = (1 + \beta)L_0$ . The banker sells a proportion  $y$  of old loans to new investors at date 1/2 at price  $P$  defined in (10) to expand lending by  $\beta L_0$ . For the banker to monitor the portfolio of loans the following incentive compatibility condition must hold

$$D_1 \leq RL^u - b^u - y \left( R - \frac{B}{\Delta p} \right) L_0,$$

where  $b^u = (B/\Delta p)L^u$  is the bonus to the banker and the last term is the return to the investors who have bought a fraction  $y$  of old loans in case the bank is solvent. Hence the maximum return that the banker can promise to her depositors is

$$D_1 \leq (1 + \beta - y) \left( R - \frac{B}{\Delta p} \right) L_0, \quad (12)$$

where  $(1 + \beta - y)$  is the share of loans still in the balance sheet of the bank at date 1. The depositors' participation condition is

$$D_1(1 - p) + p(R - \ell)(1 + \beta - y)L_0 \geq D_0 \quad (13)$$

where the face value  $D_1$  is paid in case the loans portfolio succeeds or whatever is left in case the bank is insolvent. The optimal solution is given by the maximum amount of lending fulfilling (12) and (13). Substituting date 0 balance sheet from (3), we derive the optimal capital ratio  $k_0 = (1 + \beta)k_S$ . To commit to this lending the banker has to hold  $(1 + \beta)k_S$  informed capital:  $k_S$  is needed to convince depositors to fund the bank at date 0, while an additional  $\beta k_S$  to convince new investors to provide the liquidity so to expand loans by  $\beta L_0$  at date 1/2.

Let us now consider the opposite case with macro shocks, but without new lending opportunities at date 1/2, that is  $\alpha > 0$  and  $\beta = 0$ . In this case the banker does not need liquidity at the interim date ( $y = 0$ ), but buys insurance to cover the exogenous credit losses. The capital ratio at date 0 is augmented relatively to the simple benchmark model by  $q\alpha$ , representing the capital insurance premium paid to cover the losses when the solvency shock occurs in state  $d$ . To understand the intuition of this result, we compute the maximum return for depositors in the absence of the capital insurance. This amount takes different values in the two macroeconomic states. The maximum pledgeable income to depositors in state  $u$  is

$$\left( R - \frac{B}{\Delta p} \right) L_0,$$

while in state  $d$  it is diminished by the loan losses, that is

$$\left( R - \frac{B}{\Delta p} \right) L_0 - \alpha L_0.$$

Without capital insurance, the face value of deposits is given by the minimum of these two terms, that is by state  $d$  maximum pledgeable income. Exogenous loan losses reduce the face value of deposits in state  $d$ , while in state  $u$  the banker is left with an extra-rent

$$b^u = \frac{B}{\Delta p} L_0 + \alpha L_0.$$

There is scope for smoothing income across states: by paying an insurance premium  $q\alpha L_0$  to cover the losses  $\alpha L_0$  in state  $d$ , the maximum pledgeable income in state  $d$  would be reduced just by the amount of the capital insurance premium instead the entire exogenous loan losses, i.e.

$$D_1 = \left( R - \frac{B}{\Delta p} \right) L_0 - q\alpha L_0.$$

There is also a benefit in terms of saved capital; with capital insurance the capital ratio at date 0 is  $k_0 = k_S + q\alpha$  which is smaller than the capital ratio without insurance  $k_S + \alpha(1 - p) + qp\alpha$  as it can be easily proved. State-contingent insurance boosts total lending and for this reason it dominates the solution without capital insurance. The version of our model with  $\alpha > 0$  (exogenous credit losses due to adverse macroeconomic conditions) and  $\beta = 0$  (no new lending opportunities at date 1/2) is thus a way to formalize the capital insurance ideas of Flannery (2005) and Kashyap et al. (2008).<sup>15</sup>

When  $\alpha$  and  $\beta$  are both positive, things are more complicated, although a combination of the two previous cases. To foster banker's incentives it is optimal to use capital in order to extend lending in state  $u$ . However in state  $d$  the banker needs capital to cover loan losses. There is a tension between these two different uses of capital. We compute the maximum pledgeable income to depositors in state  $u$

$$RL^u - b^u - y \left( R - \frac{B}{\Delta p} \right) L_0 = \left( R - \frac{B}{\Delta p} \right) L_0 - y \left( R - \frac{B}{\Delta p} \right) k_S L_0$$

and in state  $d$

$$\left( R - \frac{B}{\Delta p} \right) L_0 - \alpha L_0.$$

The face value  $D_1$  is given by the minimum of the two values, that is

$$D_1 = \left( R - \frac{B}{\Delta p} \right) L_0 - \max \left\{ \alpha, y \left( R - \frac{B}{\Delta p} \right) k_S \right\} L_0.$$

When  $W = \alpha - y(R - (B/\Delta p))k_S > 0$ , the face value of deposits is determined by state  $d$  maximum pledgeable income, leaving an extra-rent  $W$  to the banker in state  $u$ . Using an argument similar to the one discussed before, the optimal solution requires to transfer capital from state  $u$  to state  $d$  to smooth depositors's income across the two states. The banker might buy protection to insure for the exogenous loan losses linked to the macroeconomic downturn; for each unit of premium  $qW > 0$  the banker receives a refund of  $W > 0$  in state  $d$ . When  $W = \alpha - y(R - (B/\Delta p))k_S < 0$  instead, deposits' face value is bound by state  $u$  maximum pledgeable income, leaving an extra-rent to the banker of  $(-W) > 0$  in state  $d$ . Again, to boost lending capacity in state  $u$  the solution requires to smooth income to depositors across the two states by redistributing capital from state  $d$  to state  $u$ . The banker might sell protection, namely she receives a premium  $qW$  in both states and pays  $W < 0$  when state  $d$  occurs. To conclude, there is a tension between incentives and insurance, that is resolved in opposite ways according to the sign of  $W$ . When the macro shock dominates ( $W > 0$ ) insuring loan losses helps to restore incentives, while it destroys incentives when new lending opportunities dominate ( $W < 0$ ).

In both cases, capital requirements are tighter compared to the simple benchmark case, since  $k_0 > k_S$ . Loan losses and greater commitment to lend, although for different reasons, require holding more capital: on the one hand, in state  $d$  the additional capital is equivalent to the amount of the premium to insure depositors against expected loan losses; on the other hand, in state  $u$  additional capital is required to back the greater lending commitment arising from funding the new business opportunities.

To understand the details of the implementation of the optimal capital ratio, we compute the two (interim) state-contingent capital ratios, namely the capital ratios after the realization of the

<sup>15</sup> Chiesa (2008) considers a model, similar to our case with  $\alpha > 0$  and  $\beta = 0$ , although in her model monitoring is more valuable in state  $d$ . She shows that the optimal contract is implemented through credit derivatives on the aggregate portfolio of loans.



macroeconomic shock at date 1/2. In state  $u$ , the bank sells a fraction  $y$  of its initial loans, in order to finance a fraction  $\beta$  of new loans.<sup>16</sup> As already noted, the banker's incentive to monitor the sold loans is maintained if she retains the equity tranche of these new loans and capital charges are raised by an additional  $E_1 = yk_S L_0$ . Moreover the (unconsolidated) balance sheet of the bank at date 1/2 in state  $u$  is

$$L_0(1 + \beta - y) = E^u + (1 - p)T^u + [(1 - p)D^u + p(R - \ell)(1 + \beta - y)L_0],$$

which gives after simplification:

$$E^u = k_S L_0(1 + \beta - y).$$

Overall the bank maintains total capital  $E^u + E_1 = k_S(1 + \beta)L_0$ , equivalent to a capital ratio  $k^u = k_S(1 + \beta)$  in state  $u$ . This implies computing the capital ratio  $k_S$  on a larger lending base, i.e.  $L^u = (1 + \beta)L_0$ . Thus there is no change compared to the simple benchmark capital ratio, provided that the solvency ratio is satisfied at the consolidated level.<sup>17</sup> In particular our analysis suggests that the regulator must require bankers to maintain an equity tranche in the securitized assets and must set appropriate capital charges. Not having set those appropriate capital charges has been one of the regulatory faults at the hearth of the huge losses in the banking sector during the subprime crisis as documented by Acharya et al. (2012).<sup>18</sup>

The other state contingent capital ratio in state  $d$ , must be augmented, anticipating the deterioration of profitability. Indeed, the balance sheet of the bank at date 1/2 in state  $d$  is:

$$L_0 = E^d + (1 - p)T^d + [(1 - p)D_1 + p(R - \alpha - \ell)L_0],$$

which gives after simplification  $E^d = (k_S + \alpha)L_0$  implying a capital ratio  $k^d = (k_S + \alpha)$ . This tighter capital ratio also prevents the bank from increasing its lending in state  $d$ , which would destroy the banker's incentive to monitor her loans.

Finally, the difference between the two state-contingent capital ratios

$$k^d - k^u = \alpha - \beta k_S$$

captures the relative strength of the two motives for holding more capital in the different macroeconomic conditions. This has implications for the behavior of the optimal capital ratio during the cycle. When  $\alpha - \beta k_S > 0$  the capital ratio in state  $d$  is greater than in state  $u$  and lending is pro-cyclical (since the optimal capital ratio is tighter in downturns than in upturns), while the opposite holds for  $\alpha - \beta k_S < 0$ . In the solution the pro-cyclicality in lending implied by the optimal capital ratio is not necessarily a problem when the solvency shock is severe. However when under-investment in upturns is the main concern, the optimal solution implies anti-cyclical lending (since the capital ratio would be larger in upturns to sustain the larger lending commitment). Our solution is in line with the idea in Kashyap and Stein (2004) that capital regulation should resolve the tension between two contrasting objectives, insuring

for loan losses in downturns, while also reducing under-investment in upturns.

## 5. Discussion

Our results show that a combination of capital insurance and securitization (with appropriate capital charges) is a way to manage optimally the bank's interim liquidity needs. Our results may arise as a consequence of several assumptions in the model. Let us discuss the implications of some of these assumptions for the solution we propose in the paper.

First of all, not only investors but other banks could in principle supply liquidity at date 1/2 after the solvency shock has occurred, although they are likely to be hit by the same shock, which represents a global economic downturn (recession). As the subprime crisis has shown, a generalized freeze in interbank and money markets is not a purely theoretical possibility. Contingent instruments by contrast provide flexibility for funding at the time when new investment opportunities arise and in the contingencies in which it is desirable.<sup>19</sup> What happens instead if neither investors in financial markets nor other banks can provide the liquidity at date 1/2? If the access to financial markets is precluded at date 1/2 then one solution for the bank is to hoard liquidity at date 0 in order to be able to undertake the new business opportunities at a later date. Let us consider the consequences of such a restriction by comparing it to the second best solution in Proposition 2.

**Liquidity hoarding.** Holding liquidity in excess before the realization of the solvency shock could be a solution to avoid turning down future lending opportunities in case access to financial markets at date 1/2 is restricted. However at date 0 not all information is available. The ex-ante optimal level of liquidity to hold at date 0 is therefore different from the ex-post optimal level of liquidity at date 1/2 once uncertainty about the macroeconomic scenario is resolved, but this affects banker's incentives. To mitigate this ex-ante incentive problem, the capital ratio must be adjusted to a higher level, reducing total lending in the initial stage. By contrast, a combination of capital insurance and securitization (with appropriate capital charges) provides state-contingent liquidity when the uncertainty about the shock is resolved.

To see this more precisely, assume that a bank with total liabilities  $E_0 + D_0$ , lends  $L_0$  and hoards liquidity  $\tilde{L}_0$  at date 0 to be used later. From date 0 bank's balance sheet, we have:

$$L_0 + \tilde{L}_0 = E_0 + D_0. \quad (14)$$

At date 1/2 when new lending opportunities  $\beta L_0$  arise, the banker can grant new loans using the hoarded liquidity  $\tilde{L}_0$ . Notice that this amount cannot be made conditional upon the realization of the shock, since there is no credible commitment not to employ it later in state  $d$ . Since the state of the economy is yet unknown there is a unique optimal level of liquidity to hoard at that date 0, that is  $\tilde{L}_0 = \tilde{\alpha} L_0$ . Given that the expected surplus in (9) is increasing in the total lending size, this optimal rate is  $\tilde{\alpha} = \beta$ . It follows that the size of the loans portfolio is constant across states, i.e.  $L^u = L^d = (1 + \beta)L_0$ . It is easy to prove that the capital ratio is greater (tighter credit conditions) compared to that in Proposition 2, as stated in the following result:

<sup>19</sup> However, as clearly illustrated in 2008 by AIG's incapacity to honor its CDS commitments without State support, some form of prudential regulation is needed to guarantee that the counterparties to these contingent contracts remain solvent in the downturn.

<sup>16</sup> Notice that the money raised by selling old loans  $yL_0$  is completely absorbed by the new loans  $\beta L_0$ , leaving the banker without any idle liquidity, since  $yP = \beta$ .

<sup>17</sup> What we have in mind here is partial securitization where a portfolio of loans is sliced into several tranches and transferred as Asset Backed Security (ABS) to a Special Purpose Vehicle (SPV). Our solution implies that the regulator obliges the bank to keep the junior tranche of the ABS it creates. Furthermore the capital charge of the bank is computed on the consolidated balance sheet of the bank plus the SPV.

<sup>18</sup> Many commentators of the subprime crisis have pointed out multiple regulatory failures (see for instance Hellwig, 2009). We suggest that the Basel Committee and other regulatory bodies did not fully anticipate the implications of the securitization process for the bankers' incentives to monitor their borrowers. This paper provides policy recommendations on how to correct this regulatory failure.

**Proposition 4.** *Holding excess liquidity at date 0 entails a larger capital ratio (and thus a lower volume of loans) compared to the solution in Proposition 2.*

**Proof.** See in Appendix A.  $\square$

There are two reasons why this solution is dominated by the solution in Proposition 2. The first is that now it is impossible to implement the tough incentive scheme leading to  $x^d = 0$ : the banker is equally rewarded in the two states, but this leaves her a greater rent and reduces the repayment promised to depositors. As a consequence, the scale of activity of the bank is smaller. The second is that liquidity management is improved when transfers of funds across states occur once the realization of the shock is known. The solution in Proposition 2 guarantees a better use of bank capital, by allocating funds to the state in which liquidity is worth more. This is analogous to the analysis of corporate risk management by Froot et al. (1993) as a way to improve coordination between investment opportunities and financing policies. Our result also suggests that banks with access to securitization tend to hold less capital and increase their lending compared to other banks. This prediction finds support in Cebenoyan and Strahan (2004) as they confront the behavior of US banks: more active banks in the loan sale market tend to hold less capital and have a larger lending size compared to other banks. Also Goderis et al. (2006) find evidence that banks issuing collateralized loan obligations tend to expand their lending by 50%.

*Postponed uncertainty.* In the model with macro uncertainty we have assumed that new business opportunities arise after the realization of the macro shock. Let us discuss the effect of reversing the sequence between new lending opportunities and the macro shock. Assume that new lending opportunities arise *before* the realization of the macro shock. Under this assumption the optimal lending size must be set before the state of the economy is known, similarly to the previous case of liquidity hoarding. However, differently from before, the bank now can access financial markets at date 1/2 to obtain new funding from investors. The difference with respect to Proposition 2 is that here uncertainty is yet unresolved when deciding the optimal lending size. To see this more precisely, assume that the bank with total liabilities  $E_0 + D_0$ , lends  $L_0$  at date 0. At date 1/2 new lending opportunities  $\beta L_0$  arise, and the banker must decide a unique optimal lending size  $\tilde{L} = (1 + \tilde{x})L_0$  before the state of the economy is known. Substituting  $\tilde{L}$  into (9) the expected surplus is:

$$S = [R - p\ell - 1 - q\alpha]\tilde{L}. \quad (15)$$

Because of assumption (A3), the optimal lending size is achieved by choosing the maximum expansion rate  $\tilde{x} = \beta$ . It is easy to prove that the capital ratio is greater (tighter credit conditions) compared to that in Proposition 2, as stated in the following result:

**Proposition 5.** *When new lending opportunities arise before the macro shock, the optimal capital ratio is larger (and the lending size is smaller) compared to the solution in Proposition 2.*

**Proof.** See in Appendix A.  $\square$

The reason why this solution is dominated by the solution in Proposition 2 is that here the optimal lending size is chosen under uncertainty about the macroeconomic scenario. The lending size is now increased by  $\beta$  in both macro states, but with probability  $q$  state  $d$  realizes and the bank must cover the losses on a larger lending base compared to that in Proposition 2. Notice that the capital ratio in Proposition 4 is greater than that in Proposition 5, itself greater than that in Proposition 2. The reason behind this ranking is easily explained. In the case of no access to financial markets (liquidity hoarding) the lending base is set when uncertainty is yet unresolved. By relaxing the restriction on the access to financial

markets (postponed uncertainty), still the lending size is chosen without knowing the state of the economy. Finally when access to financial market is allowed and the decision about the lending size is taken knowing the state of the economy, the capital ratio reaches its minimum level due to the efficient use of contingent liquidity.

*Different roles for investors and depositors.* In the model we assume that banks are financed by either depositors at date 0 and investors at date 1/2. What is the difference between these two sources of funding? We postulate a difference in terms of risk appetite, in that depositors are reluctant to suffer a reduction in the face value of their deposits in the worse macroeconomic scenario, contrary to other investors in financial markets. Evidence in Levy-Yeyati et al. (2010) shows that depositors are reactive to macroeconomic shocks. Macroeconomic shocks by producing loan losses reduce the bank's ability to repay depositors; depositors then react to these shocks by withdrawing their deposits whenever they fear that the face value of deposits is affected. They conclude calling for a regulation that includes some provision for macroeconomic risks. In our model this provision is supplied by investors in financial markets, through a form of private capital insurance. If depositors were willing to absorb macroeconomic risk, in addition to the idiosyncratic risk due to the low monitoring effort of the banker, then capital insurance would be redundant, although securitization with appropriate capital charges, would still be part of the optimal solution.

## 6. Conclusion

In a model where bank monitoring is important but non-observable we have shown how a banker can maintain incentives to monitor with securitization by keeping a sufficient equity position in the sold loans. Furthermore a set of contingent capital ratios should be designed with the objective of expanding lending in upturns, while restricting the access to securitization in downturns.

Our results have implications for the design of prudential regulation. In the standard regulatory approach (e.g. Basel II) capital ratios are derived from VaR models where the threshold of bank solvency is set by an exogenous probability of bank default. Our model goes further and incorporates moral hazard considerations into prudential regulation. One of our most important results is that the optimal capital ratio should be state-dependent, since it must account for bankers' incentives in the different states of the economy. Furthermore we show that the capital ratio should not be designed with the unique objective of insuring loan losses in downturns but also with the concern for under-investment in upturns. A natural instrument for doing this is capital insurance for banks, an idea put forward by Flannery (2005) and Kashyap et al. (2008). As far as we know, our model provides the first theoretical analysis of how these capital insurance mechanisms should be structured in order to maintain bankers' incentives for monitoring loans. In the particular case where there are no lending opportunities at the interim date, our optimal solution can be implemented by a simple insurance, refunding the banker for the exogenous loan losses in downturns and by a new capital requirement increased just by the amount of the premium of this capital insurance. When instead new investment opportunities are available, securitization is part of the optimal regulatory scheme. In this case, we show how the capital requirement must be adjusted for preserving bankers' monitoring incentives.

Our paper has adopted a micro-prudential perspective in the sense that the analysis is conducted at the individual bank level. Therefore, it does not consider all the interesting questions associated with contagion and systemic risk. Also it is beyond the scope of this paper to account for dynamic regulation. However one could

extend the dynamic contract techniques developed for instance in Bias et al. (2007) to a model with aggregate shocks to determine the optimal inter-temporal contract and see how it can be implemented by a combination of securitization and contingent capital or other hybrid forms of financing. This would be an ideal set-up for studying macro-prudential regulation of large financial institutions with access to securitization.

Finally we assume that the probability of being in a recession is exogenous, although we know that bank behavior might affect the persistence of a recession. The investment side of our model is too simple to analyze the impact of a credit crunch on productive investments and hence on the business cycle. We leave for future research the task of extending our analysis to capture the dynamics of the business cycle together with optimal capital regulation.

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## Appendix A. Proofs

**Proof of Proposition 2.** Using the definition of  $k_S$  from the benchmark model, the expected social surplus in (9) can be re-written as

$$S = (1 - q) \left[ (1 - p) \frac{B}{\Delta p} - k_S \right] L^u + q \left[ (1 - p) \frac{B}{\Delta p} - (k_S + \alpha) \right] L^d, \quad (16)$$

with  $L^u \equiv (1 + x^u)L_0$  and  $L^d \equiv (1 + x^d)L_0$ . The optimal solution requires choosing the level of loans  $L_0$ , deposits  $D_0$  and a rate of growth of loans in both states  $0 \leq x^d, x^u \leq \beta$ , that maximize expected social surplus in (16) under the incentive compatibility constraints (6), depositors and investors participation conditions (7) and (8).

The expected surplus (16) is increasing in both  $L^u$  and  $L^d$  (this is because assumption (A3) implies that the NPV of loans is positive, even in state  $d$ ), therefore the two incentive compatibility constraints (6) are binding.

Once we substitute  $D_0 = L_0 - E_0$  into (7) and solve for the expected face value of deposits  $D_1$ , we have

$$(1 - p)D_1 \geq L_0 - E_0 - (1 - q)p(R - \ell)L^u - qp(R - \alpha - \ell)L^d. \quad (17)$$

Further, if we substitute the binding incentive compatibility conditions (6) into (8) and solve for the expected face value of deposits we obtain

$$(1 - p)D_1 \leq (1 - q)(1 - p) \left( R - \frac{B}{\Delta p} \right) L^u + q(1 - p) \times \left( R - \alpha - \frac{B}{\Delta p} \right) L^d - (1 - q)x^u L_0 - qx^d L_0. \quad (18)$$

Combining (17) and (18) after substituting  $x^s L_0 = L^s - L_0$  (with  $s = u, d$ ) we obtain:

$$E_0 \geq (1 - q) \left[ 1 - R + \frac{B}{\Delta p} + p \left( \ell - \frac{B}{\Delta p} \right) \right] L^u + q \left[ 1 - R + \frac{B}{\Delta p} + p \left( \ell - \frac{B}{\Delta p} \right) + \alpha \right] L^d,$$

which can be simplified into:

$$E_0 \geq (1 - q)k_S L^u + q(k_S + \alpha)L^d. \quad (19)$$

Given that the expected surplus is increasing in both  $L^u$  and  $L^d$ , condition (19) must be binding. We are thus left with maximizing  $S$ , given by (16) under the unique constraint (19). The two variables are  $L^u = (1 + x^u)L_0$  and  $L^d = (1 + x^d)L_0$ . This is a linear program. It is immediate to see that the solution implies choosing  $x^u = \beta$  and  $x^d = 0$ .  $\square$

**Proof of Proposition 3.** The maximum pledgeable income to depositors at date 1 when the banker is solvent in state  $u$  is

$$D_1^u = \left( R - \frac{B}{\Delta p} \right) (1 + \beta - y)L_0 - T^u,$$

while in state  $d$  it is

$$D_1^d = \left( R - \alpha - \frac{B}{\Delta p} \right) L_0 - T^d.$$

The depositors’ participation condition is

$$(1 - q) \{ (1 - p)D_1^u + p(1 + \beta - y)(R - \ell)L_0 - pT^u \} + q \{ (1 - p)D_1^d + p(R - \alpha - \ell)L_0 - pT^d \} \geq D_0.$$

Substituting  $D_1^u$  and  $D_1^d$  from the definitions of maximum pledgeable income, we derive

$$(1 - q)[(1 + \beta - y)(1 - k_S)L_0 - T^u] + q[(1 - k_S)L_0 - \alpha L_0 - T^d] \geq D_0.$$

Using the condition that the expected transfers across states must be zero, namely  $(1 - q)T^u + qT^d = 0$ , and substituting date 0 bank’s balance sheet in (3), gives

$$\frac{E_0}{L_0} \geq k_S + (1 - q)(1 - k_S)yk_S + q\alpha = k_S + (1 - q)\beta k_S + q\alpha.$$

that is the capital ratio in Proposition 2.

Finally, to compute the optimal amount of transfers to investors we assume that the face value promised to depositors must be constant across states, that is  $D_1^u = D_1^d = D_1$ . Taking the difference of the two pledgeable incomes, gives

$$T^u - T^d = \left[ \alpha - y \left( R - \frac{B}{\Delta p} \right) k_S \right] L_0 = WL_0.$$

From the condition  $(1 - q)T^u + qT^d = 0$ , it follows that  $T^u = qW$  and  $T^d = -(1 - q)W$ .  $\square$

**Proof of Proposition 4.** Since uncertainty is yet unresolved at  $t=0$ , excess liquidity  $L_0 = \tilde{x}L_0$  cannot be made state contingent: there is a unique level of liquidity  $\tilde{x} = x^u = x^d$ . Given that the expected surplus in (9) is increasing in this level of liquidity, the

optimal rate is  $\tilde{x} = \beta$  and thus the size of the loans portfolio at date 1 is  $\tilde{L} = (1 + \beta)L_0$ . Depositors' participation condition is

$$(1 - p)D_1 + p(R - \ell)\tilde{L} - qp\alpha\tilde{L} \geq D_0. \quad (20)$$

Given the uniform size of the loans portfolio at date 1, the minimum bonus for the banker to monitor is:

$$b^u > b^d \geq \frac{B}{\Delta p} \tilde{L}.$$

This sets an upper limit to the repayment promised to depositors, which corresponds to state  $d$  maximum pledgeable income:

$$D_1 = \left(R - \alpha - \frac{B}{\Delta p}\right) \tilde{L}. \quad (21)$$

Substituting (21) into (20) together with date 0 balance sheet in (14), delivers the minimum capital requirement:

$$E_0 \geq \tilde{k}_0 L_0,$$

where  $\tilde{k}_0 = (1 + \beta)[k_S + \alpha(1 - p) + pq\alpha]$ . It is easy to check that  $\tilde{k}_0 > k_0$ . The result is easily proven since both  $\tilde{k}_0$  and  $k_0$  are linear functions of  $q$ . At the two extremes,  $q = 0$  and  $q = 1$ , it is  $\tilde{k}_0 > k_0$ . Thus following from the linearity of the two functions,  $\tilde{k}_0(q) > k_0(q)$  for all  $q \in (0, 1)$ .  $\square$

**Proof of Proposition 5.** Since uncertainty is yet unresolved at  $t = 0$ , the lending size  $\tilde{L} = (1 + \tilde{x})L_0$  cannot differ across macroeconomic states. Given that the expected surplus in (15) is increasing in the lending size, the optimal growth rate is  $\tilde{x} = \beta$  and thus the size of the loans portfolio at date 1 is  $\tilde{L} = (1 + \beta)L_0$ . Depositors' participation condition is given also in this case by (20) and the minimum bonus for the banker to monitor is  $B/\Delta p \tilde{L}$ , similarly to the liquidity hoarding case. New business opportunities are funded through financial markets at date 1/2. Investors' participation constraint at date 1/2 can be derived substituting the constant lending size  $\tilde{L}$  and the minimum bonus for the banker into (8). We obtain the following system of equations:

$$\begin{aligned} (1 - p)D_1 &\geq (L_0 - E_0) + qp\alpha\tilde{L} - p(R - \ell)\tilde{L} \\ (1 - p)D_1 &\leq (1 - p)\left(R - \frac{B}{\Delta p}\right)\tilde{L} - q(1 - p)\alpha\tilde{L} - (\tilde{L} - L_0) \end{aligned}$$

For the two disequalities to hold at the same time the RHS of the second one must be greater or equal than the RHS of the first one. Finally substituting date 0 balance sheet from (3), delivers the minimum capital requirement:

$$E_0 \geq (1 + \beta)(k_S + q\alpha)L_0.$$

It is immediate to prove that this capital ratio is greater than the capital ratio in Proposition 2, implying a smaller lending size.  $\square$

## Appendix B. Benchmark model with continuous loan losses

Our simple benchmark model is extremely stylized. We show here that the logic of our model is preserved when we assume loan losses with a continuous probability distribution, using a specification closer to the credit risk literature.<sup>20</sup> Suppose that each loan returns either  $R$  or  $(R - \ell)$  with loan losses  $\ell$  randomly distributed according to a cumulative density function  $F(\ell)$  in the interval  $[0, R]$ . The monitoring effort of the banker  $e$  can take either of the two values  $e = \{0, 1\}$  with 1 being the higher effort. A loans portfolio of size  $L_0$  returns  $(R - \ell)L_0$ . Given that returns are observable the

reward scheme for the banker is a function of loan losses  $\tilde{\ell}$ , that is  $b(\tilde{\ell})L_0$ .

We assume further that the effort impacts only on the probability of default, but not on the amount of the loss given default, namely that the c.d.f. is separable in effort and loan losses, i.e.

$$F_e(\tilde{\ell}) = [1 - p(e)] + p(e)F(\tilde{\ell})$$

Given that the effort can take only two values we define  $p$  the minimum probability of losses given a higher effort while  $p + \Delta p$  the probability of losses in case the banker does not exert effort and thus we have that  $F_1(\tilde{\ell}) - F_0(\tilde{\ell}) = \Delta p[1 - F(\tilde{\ell})]$ . By adapting the arguments of Innes (1990), it can be shown that the optimal contract<sup>21</sup> is similar to that in the benchmark model.

Denote by  $b(\tilde{\ell})$  the remuneration per unit of loan of the banker when the level of losses is a random variable  $\tilde{\ell}$  taking values on the interval  $[0, R]$ . The optimal contract is obtained by minimizing the expected remuneration of the banker (conditional on effort) under the incentive compatibility constraint:

$$\int_0^R b(\tilde{\ell})[F_1(\tilde{\ell}) - F_0(\tilde{\ell})]d\tilde{\ell} \geq B,$$

and the constraints that  $\tilde{\ell} \rightarrow b(\tilde{\ell})$  and  $\tilde{\ell} \rightarrow \tilde{\ell} + b(\tilde{\ell})$  are both decreasing. Denoting by  $\dot{b}(\tilde{\ell})$  the derivative of  $b$ , these constraints boil down to:

$$-1 \leq \dot{b}(\tilde{\ell}) \leq 0. \quad (22)$$

Moreover, limited liability requires that

$$0 \leq b(\tilde{\ell}) \leq R - \tilde{\ell} \quad \text{for all } \tilde{\ell}.$$

This is consequence of (22) whenever:

$$b(R) = 0.$$

After integration by parts the problem becomes equivalent to

$$\begin{cases} \min \int_0^R -\dot{b}(\tilde{\ell})F_1(\tilde{\ell})d\tilde{\ell} \\ \int_0^R \dot{b}(\tilde{\ell})[F_0(\tilde{\ell}) - F_1(\tilde{\ell})]d\tilde{\ell} \geq B \\ 0 \leq \dot{b} \leq 1. \end{cases}$$

Denoting by  $\lambda$  the multiplier associated with the incentive compatibility constraint, the problem consists in finding  $\dot{b}(\tilde{\ell})$  that minimizes  $-\dot{b}(\tilde{\ell})[F_1(\tilde{\ell}) + \lambda(F_0(\tilde{\ell}) - F_1(\tilde{\ell}))]$  over  $[-1, 0]$ . The solution is bang-bang:

$$\dot{b}(\tilde{\ell}) = -1_{\{F_1(\tilde{\ell}) + \lambda(F_0(\tilde{\ell}) - F_1(\tilde{\ell})) < 0\}}.$$

As a consequence of the Monotone Likelihood Ratio Property, the set of losses  $\ell$  for which the function  $F_1(\tilde{\ell}) + \lambda(F_0(\tilde{\ell}) - F_1(\tilde{\ell}))$  is negative is an interval  $[0, \ell^*]$ . Therefore the optimal contract is:

$$b(\tilde{\ell}) = L_0[\ell^* - \tilde{\ell}]_+.$$

To summarize:

<sup>21</sup> Like Innes (1990), we restrict attention to contracts such that the marginal remuneration of the banker (as a function of loans' returns) is always between 0 and 1.

<sup>20</sup> See Pagès (2009) for similar results.



- The banker is rewarded  $b(\tilde{\ell}) = (\ell^* - \tilde{\ell})L_0$  whenever losses  $\tilde{\ell}$  do not exceed the threshold  $\ell^*$  and 0 if losses are above this threshold. Thus  $\ell^*$  can be interpreted as the bank's default threshold.
- The bank's default threshold  $\ell^*$  is determined by the incentive compatibility condition:

$$\int_0^{\ell^*} [F_1(\tilde{\ell}) - F_0(\tilde{\ell})] d\tilde{\ell} = B,$$

which in our special case becomes:

$$\int_0^{\ell^*} [1 - F(\tilde{\ell})] d\tilde{\ell} = \frac{B}{\Delta p}.$$

The default threshold  $\ell^*$  is the minimum value that provides the banker who exerts a monitoring effort (distribution of losses  $F_1(\tilde{\ell})$ ) with an incremental expected gain (with respect to the case where she shirks, and the distribution of losses is  $F_0(\tilde{\ell})$ ) at least equal to the benefit  $B$  from shirking.

- The minimum capital ratio must be set equal to the net expected shortfalls

$$\frac{E_0}{L_0} \geq \int \max(\tilde{\ell}, \ell^*) dF_1(\tilde{\ell}) - (R - 1).$$

There are two fundamental differences with the VaR approach to prudential regulation. First, the capital requirement is meant to cover not the Value at Risk, but the net expected shortfalls. This means that it covers the expected losses above the default threshold  $\ell^*$ , net of the nominal excess return  $(R - 1)$  on loans. The second difference is that the default threshold  $\ell^*$  is not given by an exogenously determined probability of default but by the incentive compatibility condition. This example shows that also a more realistic model of default risk bears the same implications for the optimal capital requirement of our simple model in Section 3.1.

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